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**MEETING THE DURUM WHEAT QUALITY REQUIREMENTS
OF AN EVOLVING PROCESSING INDUSTRY:
PAST, PRESENT AND FUTURE TRENDS.**

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Introduction

The concept of durum wheat quality is complex and confusing. Durum wheat quality criteria are continually evolving in response to technological advances in durum wheat milling and secondary processing. Quality factors such as protein content, gluten strength and color have different priorities in various durum wheat markets, and different players within the grain industry have different definitions of quality. The farmer is interested in maximizing profit, so is primarily concerned about agronomic performance, although processing quality influences marketability. The importing agent demands reliability of supply, and expects value for price. The semolina miller appreciates wheat cleanliness and uniformity, and wants to achieve a high yield of semolina within customer specifications. The pasta or couscous manufacturer makes specific demands on the semolina miller on factors such as particle size distribution, refinement (specks, brightness, ash content), protein content, gluten strength, and color.

Globalization and increasing competition in the pasta industry is making it more important that processors produce pasta products with quality that is consistent over time, among regions in a country, and even from country to country. Consumers are becoming more discriminating in their quality requirements, and variability in product quality is less acceptable, particularly for high end or premium products.

The future challenge will be to implement durum wheat variety development, production and grain handling systems capable of consistently producing and segregating wheat to meet the demands of modern processing technology. Farmers must grow varieties of good intrinsic quality, and the wheat must be segregated efficiently according to physical condition and specific quality attributes.

In each case, a firm understanding of the relationship between durum wheat quality characteristics and end product quality is essential. This presentation will review how the Canadian durum wheat variety development program has evolved over the past 50 years in response to market demand and technological change. The more important durum wheat and pasta quality factors will be identified, and their future significance will be considered in light of technological advances in durum wheat processing and changing consumer demands.

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The Canadian Concept of durum wheat quality

Canada has an enviable reputation as a reliable supplier of high quality durum wheat. Exclusive of price, the attributes of Canadian durum wheat that attract demand are safety, reliability of supply, uniformity and consistency within and among shipments, and good milling and end product quality.

Grain safety is becoming a significant marketing factor. Consumers are demanding safe food, governments are introducing tough legislation, and buyers are demanding certification and assurances. The safety of Canadian durum wheat is assured thanks to a strict quality assurance program that ensures freedom from unacceptable levels of chemical residues, mycotoxins and trace elements. Ongoing monitoring of grain shipments by the Grain Research Laboratory (GRL) confirms this high quality and forms the basis for statements of assurance on grain safety.

Reliability of Canada as a supplier of durum wheat is ensured by the great expanse of fertile plains in western Canada. Favorable soil and climatic conditions, particularly in the south central region of western Canada, have allowed the annual production of about four million tonnes of durum wheat in recent years (Figure 1).

The Canadian quality control system, which includes strict grading standards, a bulk handling system, and strict control of varieties, has evolved with the primary goal of achieving uniformity and consistency within and between shipments. The durum wheat growing area is on average well over 1000 km from the nearest ocean port, making movement to export position complex and costly. An important redeeming feature is that each step of the way, from farmer deliveries to primary elevators, to marshaling of grain cars prior to shipment to export position, and binning of like grade at terminal elevators, durum wheat of diverse origin is combined. Regional variability is eliminated, imparting uniformity between lots of like grade.

Strict control of registered wheat varieties sets Canada apart from other wheat exporters. Before a variety can be registered in Canada for any wheat class, it must undergo careful scrutiny for agronomic performance, disease resistance and end-use quality. Variety control guarantees that Canadian durum wheat that looks good (i.e., that is sound and free of environmental damage) meets the predetermined intrinsic quality requirements for the Canada Western Amber Durum (CWAD) wheat class, and may be safely put into the milling grade for which it qualifies.

The requirement that only varieties of proven high intrinsic quality can be registered for the milling grades is the cornerstone of quality assurance of Canadian wheat. In the case of the CWAD class, the variety Hercules is the minimum quality standard. As will be discussed in more detail later, Hercules-type quality was defined on the basis of industry requirements 30 years ago. Since that time Canada has gained close to 70% of the world export market in durum wheat with varieties that are based on the Hercules model of quality.

It takes over 10 years from the time of the initial cross until the commercial release of a durum wheat variety. That means that changing quality requirements need to be anticipated or identified early, so plant breeders are given proper guidance for selection. To ensure continued success as the major supplier of durum wheat to the world, Canada is addressing the following questions:

- Is the Hercules model of quality still relevant today?
- Does the concept of releasing only varieties with Hercules-type quality (or only releasing varieties that meet some future revised model of quality) allow CWAD to perform well under all processing conditions, and to compete effectively in all markets?

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Canadian durum wheat quality screening before the development of Hercules

Durum wheat was introduced into western Canada in the late 19th Century, but for many years there was

little effort expended in Canada to develop new varieties (Irvine 1965; Matsuo 1993). The first durum wheat variety developed in Canada, Stewart 63, was not released until 1963. At that time Mindum, a variety developed in the United States was the quality standard. Mindum was registered in Canada in 1925. Other American varieties registered in Canada included Carlton (1944), Stewart (1946), Nugget (1952) and Ramsey (1957). The Algerian variety Pelissier was registered in Canada in 1929.

A primary breeding consideration at that time in both the United States and Canada was a serious stem rust epidemic in the 1950s and 1960s. Ramsey and Stewart 63 became the predominant varieties in Canada in the 1960s because of their stem rust resistance. As seen in Figure 1, there were surges in durum wheat production in Canada in the mid-1950s and mid-1960s because the bread wheat lines available at that time were more susceptible to stem rust than durum wheat.

A durum wheat quality evaluation program was established at the GRL in 1934. Binnington (1939) described test procedures for determining spaghetti color, mechanical strength and cooking characteristics. Although the importance of cooking quality was recognized from the start, the primary screening criteria related to color because cooking quality was difficult to standardize. Protein content and gluten strength were not considered because they had not yet been recognized as primary determinates of cooking quality.

Screening for color remained the main quality priority in the Canadian breeding program until the late 1950s because of a revolution that took place in the pasta processing industry (Irvine 1965). In the 1930s continuous extrusion using an extrusion auger was introduced, and the industry rapidly converted from a batch process to a continuous automatic process. The continuous process improved the color of pasta because a vacuum could be applied to the dough, producing a bubble-free product with greater depth of color. In addition, Teflon inserts for die were introduced which gave the pasta a smoother, and therefore brighter, surface.

During this period durum wheat research at the GRL in support of the Canadian breeding program also centered on pasta color, and the elucidation of factors associated with color. Irvine and Winkler (1950) found that the destruction of yellow pigment was associated with the presence of an enzyme, lipoxygenase. In another study Irvine and Anderson (1953) concluded that a major factor associated with differences in semolina yellow pigment and lipoxygenase activity was genetic variability in durum wheat varieties. Matsuo and Irvine (1967) reported that a soluble colored protein is responsible for varietal differences in pasta browning.

All of the early Canadian durum wheat varieties had low yellow pigment content by the standards of today (Table 1). However, screening procedures were in place to ensure that yellow pigment levels would improve. Nugget, which was developed in North Dakota, USA, was the first North American durum wheat line released with superior color characteristics. According to Irvine (1965) Nugget had two to three times the yellow pigment content of other Canadian and American durum varieties at that time, and low lipoxygenase activity. Nugget proved to have inferior agronomic performance, so was never widely grown, but it provided a source of high yellow pigment to durum wheat breeders in the subsequent development of successful high yellow pigment varieties.

During this period Italy, an important durum wheat market for Canada, was espousing strong gluten as a prerequisite for good cooking quality. With the exception of Pelissier, all Canadian durum wheat varieties had weak extensible gluten (Table 1). After 1955, when a special grade Extra No 4 CWAD was established to segregate Pelissier because of its poor spaghetti color, Italy preferred to purchase it over other CWAD grades.

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The development of Hercules

Successful marketing of the Extra No 4 CWAD grade underscored the Italian preference for strong gluten varieties, and made improvement of gluten strength of Canadian durum wheat varieties a priority in the 1960s. The problem was that a good reliable test for gluten strength was not available. As seen in Table 1 a gluten stretching test that measured the time for a gluten ball to stretch 10 cm under its own weight was being used in the Canadian durum wheat quality screening program, and the properties of wet gluten also could be examined. Both tests were often inconclusive because the results depended on the skill of the operator, and small differences in gluten strength were difficult to quantify.

Irvine et al (1961) developed a Farinograph test in which semolina dough is mixed at pasta absorption, i.e. about 30%, that discriminates varieties according to gluten strength. As seen in Figure 2, the stronger gluten associated with Pelissier, Hercules and Wakooma is readily apparent from longer dough development time, more wild curve, and less rapid drop in dough consistency compared to Mindum, Stewart 63 and Wascana.

The Farinograph test was not applicable to early generation testing because it required relatively large samples and was too slow. Without an early generation test, the selection of strong gluten lines was inefficient, inhibiting the development of varieties with improved strength. That problem was solved by Bendelow (1967), who developed a micro-milling and micro-mixograph procedure that required only about 25g, and was simple, rapid and reliable.

Strong gluten characteristics do not guarantee good cooking characteristics (Matsuo 1993). The development in the 1960s of the GRL tenderness tester by Matsuo and Irvine (1969, 1971) provided a reliable instrument for assessing texture of cooked spaghetti, and made it possible to select varieties with good cooking quality. Now the Canadian durum wheat breeding program was poised to produce improved varieties. Hercules, registered in 1969, was the first variety that combined high yellow pigment content, strong gluten, good pasta color (i.e. no evidence of browning as evident from a low dominant wavelength) and good cooking quality (Figure 2, Table 1). Although the importance of gluten strength in durum wheat variety development was now recognized, spaghetti color remained the primary quality objective. Factors such as lipoxygenase activity, pigment loss in spaghetti during processing and degree of brownness were carefully considered (Table 1). As a result, in 1971 it was decided to register Wascana instead of Wakooma because the former has high yellow pigment content which results in intense spaghetti color despite a relatively high lipoxygenase level. By 1973 the merits of Wakooma, which has comparable yellow pigment content to Hercules, but is significantly stronger than Wascana, were recognized, and it became a registered CWAD variety. Wakooma and Wascana became the dominant varieties within a few years, comprising over 75% of the crop by the late 1970s.

The rapid acceptance of Hercules and other varieties with improved quality resulted in a rapid improvement in CWAD export cargo quality (Figure 3). The quality improvement of Hercules over previous varieties was so marked that in 1970 it replaced Mindum as the standard for quality in the CWAD breeding program. The introduction of the Hercules quality model was an overwhelming marketing success (Figure 1). During the 1960s the average durum wheat production in Canada was less than 500 thousand tonnes. That rose to over two million tonnes during the 1970s. Maintaining the Hercules model of quality since that time has resulted in a sustained increase in production to over four million tonnes during the 1990s.

Improved pasta-making quality was not the only emphasis during the development of Hercules, Wakooma and Wascana. It was recognized that improvement in agronomic performance was of equal importance if the new varieties were to meet quick acceptance by Canadian farmers. As seen in Figure 4 Hercules, Wascana and Wakooma all have significant yield advantages over previously released varieties, and varieties released since that time have continued to show yield improvements (McCaig and Clarke 1995).

The success of Hercules-type quality in Canada spurred American durum wheat breeders to develop strong gluten varieties also. By the late 1970s the first two American strong gluten varieties, Edmore and Vic, were released out of the North Dakota breeding program and were enthusiastically endorsed by the American pasta industry (Donnelly 1980).

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Factors that have influenced quality targets for current Canadian durum wheat varieties

The basic quality criteria that led to the development of Hercules and other strong gluten North American varieties, which include a high yield of highly refined semolina, high protein content, strong gluten and good pasta cooking quality, remain valid today, and are likely to remain valid for the foreseeable future. However, over the past 20 years changing market forces, evolving processing technology, and improved quality screening techniques have made it necessary for Canada to refine quality targets.

As described above, Hercules was developed almost 30 years ago in response to market demand for stronger gluten by Italy. At that time Italy was the most important overseas market for Canadian durum wheat. Thirty years ago color was not considered important in Italy, as evident from a preference for purchasing Extra No 4 CWAD (Pelissier), which had poor color, before the Hercules quality era began. As a result, although color was considered important, gluten strength and cooking quality were given greater emphasis in durum wheat variety selection in Canada. The Extra No 4 class was discontinued in the early 1970s because of the rapid acceptance of the stronger Hercules-type varieties.

Since the development of Hercules other high quality markets like the United States, Japan, and Venezuela have become important customers of Canadian durum wheat. Ever since the development of Nugget, high yellow pigment content has been an essential component of high quality semolina in the United States. Similarly, other important markets like Japan and Venezuela consider high yellow pigment content important. Today the Canadian domestic market also places more emphasis on color than before, because of influence from the American industry. The color of Canadian durum wheat is considered adequate in all markets, but in order to provide better acceptance efforts are underway to develop varieties with more yellow pigment. Kyle has comprised over 50% of the area seeded to CWAD in the past several years. As seen in Table 2, the three most recently registered varieties, Plenty (1990), ACMelita (1995) and DT484 (1996) have higher yellow pigment content than Kyle, resulting in more intense pasta color (higher b* value). Other promising lines still undergoing evaluation, have even greater pigment content. As a result the color of CWAD should improve in the future as the new varieties gain in importance.

Screening for yellow pigment in the Canadian durum wheat breeding program has been aided by the use of visible-near infrared (V-NIR) spectroscopy. McCaig et al (1992) have applied the technology to estimate yellow pigment levels on ground samples, and more recently Edwards et al (1996) have developed a procedure that uses whole grain samples. The advantages of V-NIR are that it is rapid and avoids the use of n-butanol, a flammable noxious solvent used in the reference method. The use of whole grain samples has the added advantage of being nondestructive, preserving precious early generation material.

There is general agreement that protein content is a fundamental durum wheat quality factor because of its relationship to pasta cooking quality (Matsuo et al 1982, Autran et al 1986, D'Egidio et al 1990). The relationship is complex and is influenced by other factors, but generally as protein content increases, pasta becomes firmer and less sticky. As a result, maintaining or improving protein content in CWAD varieties has remained a primary goal of Canadian durum wheat breeders. As seen in Table 2 recently released CWAD varieties are equal to or superior to Hercules in protein content.

For many years Canada met the protein content specifications of discriminating customers by registering only varieties with intrinsically high protein content, and by specifying minimum hard vitreous kernel (HVK) levels for the top CWAD grades. Despite these efforts, for the past several years exceptionally high rainfall in the durum wheat growing area has resulted in a sharp decline in CWAD protein content. Even the No. 1 CWAD grade has declined in protein content, despite maintaining the traditional grade specification of a minimum of 80% HVK (Figure 5). This is because, although durum wheat vitreousness is related to protein content, the relationship differs among varieties, and is affected by environment.

The low protein content of recent CWAD harvests has been a problem to Canada because exact adherence to minimum protein content specifications is becoming an accepted part of durum wheat sales agreements. Some countries have legislation and labeling laws in place which stipulate minimum protein levels in the finished product. Therefore, to meet the requirements of premium quality markets Canada now segregates the top three CWAD grades on the basis of protein content so that minimum protein content specifications can be met. Canadian farmers are being paid a premium for high protein durum wheat to encourage them to add more nitrogen fertilizer. These measures, and a return to more normal weather patterns, should result in a return to higher protein content in CWAD in the future.

HVK levels remain a specification in CWAD grades and an important durum wheat variety selection criterion because nonvitreous (starchy) kernels are softer than vitreous kernels. The softer texture of nonvitreous durum wheat results in a lower yield of coarse semolina (Dexter et al 1988). Coarse semolina remains an asset in couscous manufacture, but improved extrusion press technology has caused a move to finer granulation in pasta processing. As a result, the importance of HVK to durum wheat milling quality may decline.

The dramatic change in pasta drying technology over the past twenty years has had a profound effect on raw material standards. First came the introduction of high temperature (HT) drying (60°C - 85°C) (Pavan 1979; Manser 1980). HT drying was quickly accepted by the pasta-making industry because of improved hygiene and improved cooking quality compared to traditional lower temperature drying. In the past few years the application of ultra-high temperature (UHT) drying (85°C - 110°C) has become common, with drying times as short as ≈ 4 -5 hr. for long goods and ≈ 2 -3 hr. for short goods (Pollini 1996).

A major impact of HT and UHT drying technology on the pasta industry has been the production of pasta with acceptable, or even superior cooking quality, from mediocre quality raw material (Malcolmson et al 1993). When low temperature (LT) drying ($<60^{\circ}\text{C}$) is used, the cooking quality of durum wheat pasta is clearly superior to pasta made from common wheat, particularly when the product is overcooked (Figure 6). When HT drying is used the cooking quality, particularly surface stickiness of pasta made from 100% common wheat farina, or mixtures of durum semolina and farina, improve dramatically (Table 3). Similarly, although protein content is still a factor in determining the texture of HT-dried pasta, the texture of HT pasta from low protein durum wheat semolina is better than that of LT-dried pasta (Table 3). The color of the final product is also affected by drying technology. HT and UHT drying can improve color, but care must be taken to ensure that off colors (brown to red) are not developed as a result of browning reactions (Dexter et al 1984).

The influence of drying technology on pasta properties brings traditional criteria for durum wheat selection into question. For example, there is evidence that under HT and UHT drying conditions protein strength has less influence on pasta cooking quality than under LT drying conditions (D'Egidio et al 1990, 1996). Enzymatic browning due to peroxidase has been shown to affect pasta color regardless of whether pasta is dried at LT or HT, but the interrelationships between varieties, growing environment, drying procedure and semolina extraction rate are not well understood (Kobrehel and Abecassis 1985).

New technology in industry requires understanding of and simulation of that technology in variety screening. As a result, in the 1980s a great deal of work was done at GRL to determine the implications of HT drying on pasta quality, and to develop drying cycles for quality screening that conformed to those being marketed by pasta equipment manufacturers (Dexter et al 1981a). An instrumental procedure for evaluating spaghetti stickiness was developed, permitting verification that HT drying overcomes pasta stickiness (Dexter et al 1983a, 1983b). In 1995, in response to industry acceptance of UHT drying, GRL purchased a new drier to allow development of UHT drying cycles. Research is currently underway to verify whether established screening tests for gluten strength and color predict the quality of UHT-dried pasta.

Of equal importance, it is necessary to develop milling procedures that give results that relate well to commercial milling potential (Matsuo and Dexter 1980). Improvement of durum wheat semolina milling procedures has been an ongoing priority at GRL for many years (Dexter et al 1982). Extraction rate has been increased (Tables 1 and 2), without sacrificing precision and accuracy (Dexter et al 1990).

Another major influence on wheat variety development has been the development of new screening techniques. These techniques make variety selection more efficient, but can also have implications in wheat marketing. An example is the sodium dodecyl sulfate (SDS)-sedimentation test developed in the United Kingdom by Axford et al (1978) to select for gluten strength in common wheat. The SDS test quickly became established as an early generation selection test in both the Canadian and American durum wheat breeding programs (Dexter et al 1980; Quick and Donnelly 1980). The SDS test was embraced by the American pasta industry as a durum wheat purchasing specification to guarantee strong gluten because it was rapid and gave a quantifiable result. Therefore, although the SDS test was a great asset in selecting strong gluten durum wheat lines early in durum wheat breeding programs, it impeded the marketing of commercial durum wheat parcels that did not meet industry SDS standards.

The growing acceptance of the SDS test in the early 1980s created market forces that impacted on the variety choice for some Canadian farmers. As mentioned earlier, the gluten quality of Wascana is inferior to other varieties released during the Hercules era. Wascana quickly became popular with Canadian farmers because of its outstanding agronomic properties. However, it had a low SDS value. In the 1980s a publicity campaign was launched to encourage farmers growing Wascana to grow a recently released variety Kyle, which matched the agronomic potential of Wascana, but had stronger gluten. Canadian farmers recognized the importance of meeting the quality demands of their customers, so the campaign was successful, and many farmers switched. Kyle remains the predominate CWAD variety today.

Recently the gluten index test has been touted as a good index of durum wheat gluten strength (Cubadda et al 1992). As seen in Table 2, Hercules and the currently popular CWAD varieties Kyle and Plenty have relatively low gluten index values. However, if the gluten index test becomes a quality specification the higher values associated with ACMelita, DT484, and other lines still undergoing testing in the Canadian breeding program will protect the marketability of CWAD in the future.

A significant development in wheat variety development has been the worldwide trend in recent years to bring together breeders, geneticists and cereal chemists in a cooperative effort. The discovery by Damidaux et al (1978) that two durum wheat gliadin bands separated by electrophoresis, designated 42 and 45, are markers for weak and strong gluten, respectively, revolutionized durum wheat breeding. Wascana was confirmed to be a weak band 42 type (Kosmolak et al 1978), and since then all varieties registered into the CWAD class have been strong band 45 types.

The discovery that specific proteins are markers for gluten properties spurred more research to gain a better understanding of the genetic basis for durum wheat gluten strength (Liu et al 1996). It is now known that the causal effect of superior strength of durum wheat lines with the gliadin 45 band is due to specific low molecular weight glutenin subunits (Pogna et al 1988). Some high molecular weight glutenin subunits also influence pasta cooking quality, but to a lesser effect (Pogna et al 1990).

Canadian durum wheat breeders are using monoclonal antibodies raised against specific gluten proteins as aids to select for gluten strength. Clarke et al (1993) described how progeny of gliadin band 45 and band 42 parents that carry the allele for gliadin band 42 could be eliminated at the F2 stage by that technique. There is still a range of strength within the band 45 lines, so further selection is done at the F4 stage using the SDS-sedimentation test. Kovacs et al (1995) have reported how durum wheat lines with specific high molecular weight glutenin composition can be selected using monoclonal antibodies. These techniques make early generation screening in the Canadian durum wheat breeding program more efficient, thereby increasing the proportion of lines with desirable quality traits that are selected for later generation testing.

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Defining optimum gluten strength for future Canadian durum wheat varieties

In the next few years defining a precise target for gluten strength will be a major consideration in the Canadian durum wheat variety development program. Plant breeders have at their disposal genetic material with a wide range of gluten strength characteristics. Hercules has very different physical dough characteristics compared to the popular Italian variety Simeto (Figure 7). Simeto is much stronger than Hercules.

Physical dough tests like the Alveograph and Mixograph are used in most durum wheat quality screening programs to measure gluten strength characteristics (Dick and Youngs 1988). Caution must be exercised, however, when interpreting curves obtained at constant water absorption, which is the usual procedure when using the Alveograph. Variation in intrinsic absorption, along with protein content differences, can make interpretation of gluten properties by the standard Alveograph procedure misleading. Simeto has a much higher Farinograph water absorption than Hercules (Figure 7). When the Alveograph curve of Simeto is obtained at 58% water absorption rather than the usual 50%, thereby taking into account the intrinsically higher water absorption of Simeto, the Simeto Alveograph curve becomes more balanced (Figure 7). Durum wheat is very hard, so starch damage and particle size distribution, which influence water absorption, can be influenced by inadequate control of roller mill grinding conditions (Dexter et al 1994). Therefore, when using the Alveograph as a physical dough (gluten strength) indicator, it is important to mill all durum wheat samples under carefully controlled conditions.

For dried pastas, in particular long goods, major North American and European pasta manufacturers have indicated that strong gluten durum wheat is preferable. For example, Italian breeders are developing durum varieties with Alveograph P/L (ratio of height to length) of about 1.5 to 2.5, and Alveograph W (work, derived from area under the curve) of around 200 to 250. For top quality long goods, some manufacturers request durum wheat with a W over 300. This is contrary to previous studies at GRL which suggested that medium gluten strength varieties may be preferable (Dexter et al 1981b).

The increasing acceptance of Alveograph specifications in durum wheat purchasing makes it mandatory that Canada rethink the Hercules model of quality. There are lines currently in the Canadian durum wheat breeding program with a range in gluten strength and Alveograph properties. The two varieties released most recently in Canada, ACMelita and DT484 and other advanced lines have significantly greater strength than Hercules (Table 2 and Figures 7 and 8). Other lines which are even stronger, are entering the final stages of testing. However, it is interesting to note that although the release of Hercules types in the 1970s resulted in a significant improvement in pasta cooking quality (Table 1), there is no evidence that the increased strength of ACMelita and DT484 results in further improvement (Table 2).

An emerging market force that may define optimum durum wheat gluten strength is increased interest in defining the best quality attributes for durum wheat for bread (Liu et al 1996). Durum wheat has a long tradition of baking in Mediterranean countries (Quaglia 1988). Common wheat baking research has shown that for best baking performance there needs to be a balance between gluten strength and gluten extensibility (Tipples et al 1982). In addition, the type of baking process (long or short, straight dough or sponge-and-dough) dictates optimum gluten strength requirements. Hercules produces short process bread with a superior volume and finer crumb structure than Simeto. The short mixing requirement of Hercules ensures that full gluten development is achieved at the mixing stage in short process baking, and dough extensibility results in good oven response. However, durum wheat with the strength of Hercules does not have adequate strength to make satisfactory bread by longer processes (Dexter et al 1994). The moderate increase in strength of ACMelita, and DT484 compared to Kyle and Plenty is evident from longer mixing times and greater energy input during mixing under short process baking conditions (Table 4). Research is currently underway at the GRL to evaluate the impact of durum wheat gluten strength on mixing tolerance and fermentation tolerance for longer baking processes.

It must be appreciated that on a global basis only a small amount of durum wheat is used for baking of pan-style and hearth-style bread. The use of durum wheat in North Africa and the Middle East for producing flat breads, which are of almost limitless variety, and have diverse quality requirements, is at least as important (Faridi 1988). Also, durum wheat for baking is often used in blends with common wheat. Breeding durum wheat for pasta and couscous (which has similar quality criteria to pasta) must remain the prime consideration in durum wheat variety development, because those two products account for over 80% of durum wheat consumption worldwide.

Increasingly popular niche uses of durum wheat underscore the need to breed varieties with gluten that combine gluten strength with extensibility. Instant pasta has thinner walls and may need more strength to standup to processing. On the other hand, for laminated pasta, which includes much of the increasingly popular fresh pasta on the market today, more extensible gluten should be an asset for sheeting. If gluten strength is increased too much, then it may become too inextensible for use in laminated fresh pasta and egg pasta noodles, and for some types of durum bread.

Defining the target for gluten strength in CWAD is a hard decision because Canada has gained close to 70% of the world export market in durum wheat with varieties that are based on the Hercules model of quality. To help in making this decision we are maintaining close dialogue with users of Canadian durum wheat to keep informed of their quality requirements. In addition, we are evaluating a wide range of varieties from diverse origins that differ in gluten strength to determine the optimum level for the best pasta and bread-making characteristics.

It may be that the proliferation of durum wheat products and the increasing sophistication of durum wheat processors will make it impossible for general purpose varieties to satisfy the quality criteria of some niche products, or to meet the specifications of the most demanding markets. The moderate increase in gluten strength associated with the new varieties ACMelita and DT484 should be universally appreciated. It remains to be determined whether varieties with even greater strength are appropriate for the CWAD wheat class, or whether stronger durum wheat varieties should be segregated from the CWAD class for customers with extra-strong gluten requirements.

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Abbreviations used

CWAD = Canada Western Amber Durum

GRL = Grain Research Laboratory

HVK = hard vitreous kernels

HT = high temperature

LT = low temperature

SDS = sodium dodecyl sulfate sedimentation test

UHT = ultra high temperature

V-NIR = visible-near-infrared reflectance spectroscopy

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PAST, PRESENT AND FUTURE TRENDS.**

Presented at the *Pavan Mapimpianti 50th Anniversary Durum
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October 23 to 26, 1996.

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Tables 1 to 4

Table 1.
Some quality characteristics of cultivars from the 1969 Canadian durum wheat quality screening program.

Property	Mindum	Stewart 63	Pelissier	Hercules	Wakooma	Wascana
Wheat:						
Protein content, %	13.8	13.9	14.2	14.8	14.4	13.8
Pigment content, ppm	6.0	5.9	5.4	7.2	7.0	8.7
Lipoxygenase, units	53	73	140	71	78	103
Semolina yield, %	58.8	59.7	59.7	58.9	60.1	58.1
Semolina:						
Ash content, %	0.55	0.55	0.59	0.59	0.56	0.52
Gluten stretch, min	18	4	>300	42	>300	34
Spaghetti (Dried at 39°C):						
Dominant wavelength, nm	576.0	576.3	576.6	576.1	576.3	576.5
Pigment content, ppm	4.3	4.3	3.6	5.5	5.6	6.7
Pigment loss, %	12.4	8.5	18.9	12.3	10.8	17.0

Cooking score, units	5	5	14	12	24	16
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Table 2.
Some quality characteristics of varieties from the 1995 Canadian durum wheat quality screening program.

Property	Hercules	Kyle	Plenty	ACMelita	DT484
Wheat:					
Protein content, %	12.7	12.6	12.7	12.6	13.0
Pigment content, ppm	7.4	7.7	8.6	8.4	8.7
SDS-sedimentation, mL	31	31	30	42	39
Semolina yield, %	65.1	63.6	65.2	66.0	64.2
Semolina:					
Ash content, %	0.66	0.60	0.63	0.71	0.62
AGTRON color, %	79	80	78	78	76
Gluten index, %	11	4	2	55	34
Spaghetti (Dried at 70°C):					
Dominant wavelength, nm	576.5	576.4	576.6	576.3	576.3
b*	59.1	60.8	62.3	63.9	63.3
Cooking score, units	35	34	36	38	33



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Table 3.
A comparison of the cooking quality of LT-dried (39°C) and HT-dried (70°C) spaghetti.

Raw material	Dried at Low Temperature			Dried at High Temperature		
	Cooking Score, units	Cooking Loss, %	Stickiness, N/m2	Cooking Score, units	Cooking Loss, %	Stickiness, N/m2
100% Hercules						
12.9% protein	10	5.7	543	11	5.6	547
15.3% protein	12	6.1	510	25	4.4	537
100% Macoun						
12.3% protein	9	6.2	720	10	5.4	547
15.4% protein	13	5.6	683	17	4.5	503
Admixes of CWAD and CWRS						
100% CWAD	9	5.2	657	13	5.0	593
50% CWAD	7	5.3	770	8	4.9	627
100% CWRS	4	4.9	950	5	4.7	717

Source: Dexter et al 1983b.



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Table 4.
Short process baking quality of some Canadian durum wheat varieties from the 1995 Canadian durum wheat quality screening program.

Property	Kyle	Plenty	ACMelita	DT484
Baking absorption, %	60	57	61	60
Mixing time, min	7.1	6.0	10.4	9.9
Mixing energy, whr/kg	5.4	4.8	6.7	8.2
Loaf volume (200g flour), cc	1600	1615	1695	1625
Specific volume, cc/g	5.3	5.4	5.7	5.4
Bread appearance, units	5.3	5.3	5.2	5.1
Crumb structure, units	5.2	6.0	6.0	5.9
Crumb color, units	6.1	6.1	6.4	6.4
Total bread score, units	27	28	34	31



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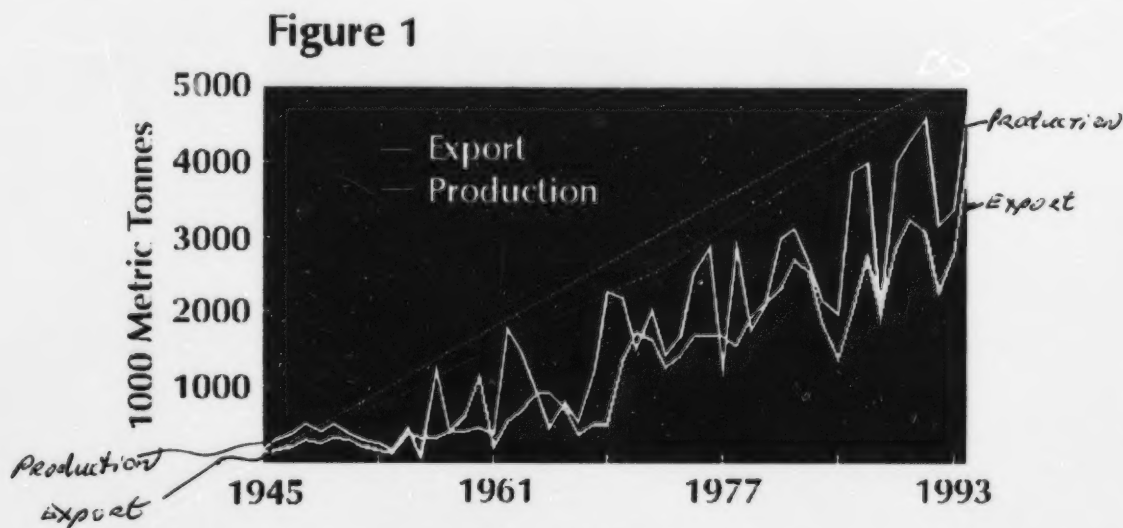
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Figures 1 to 6

Figure 1. Production and exports of durum wheat in Canada by year.



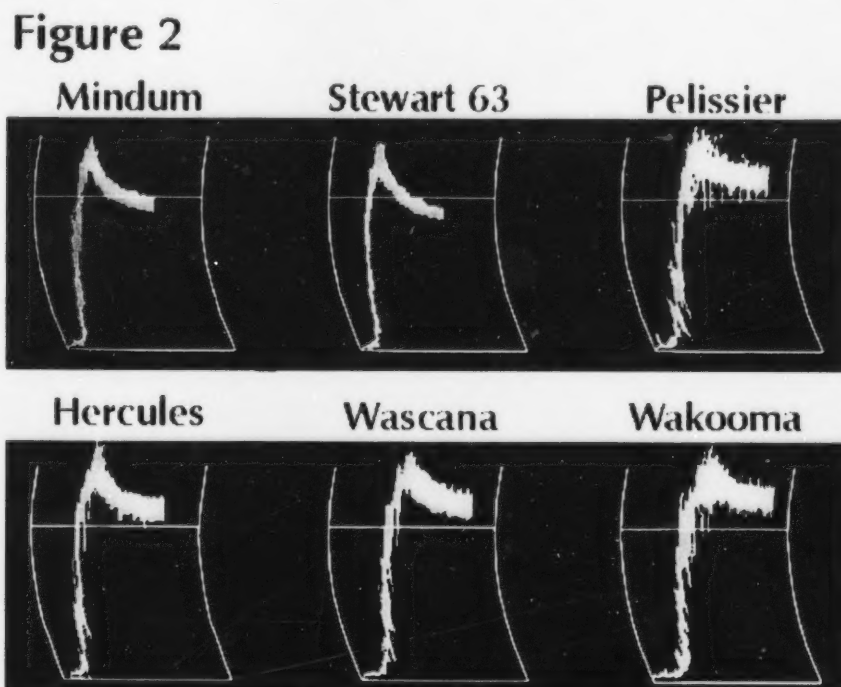
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Figure 2. Pasta dough absorption Farinograms of some Canadian durum wheat varieties.



Source: 1969 Canadian durum screening program

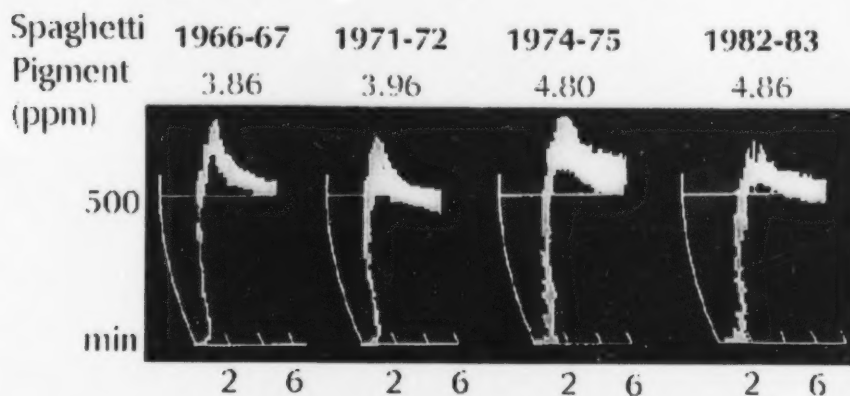
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Figure 3. The improvement in CWAD pigment content and Farinograph pasta dough strength following the release of Hercules and other improved varieties.

Figure 3



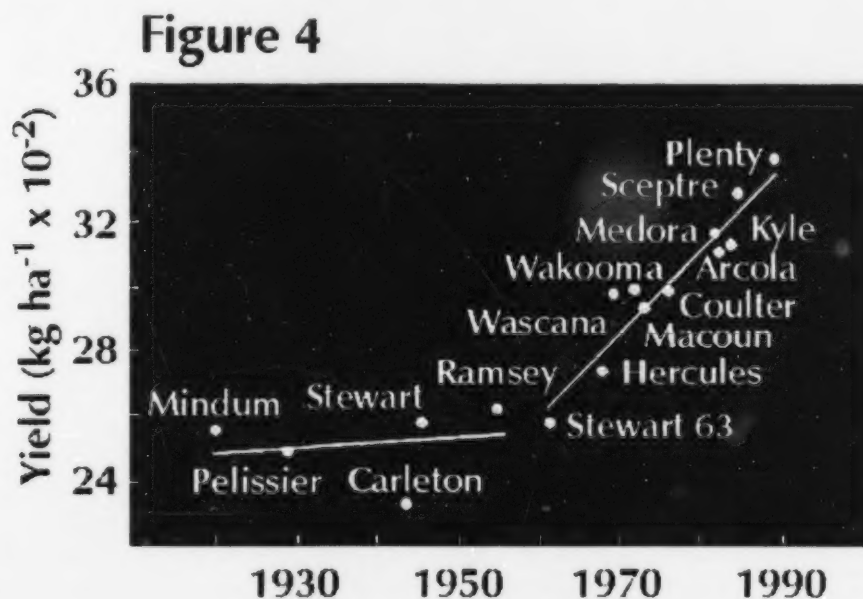
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Figure 4. The yield of registered Canadian durum wheat varieties plotted against registration date.



Year of Registration

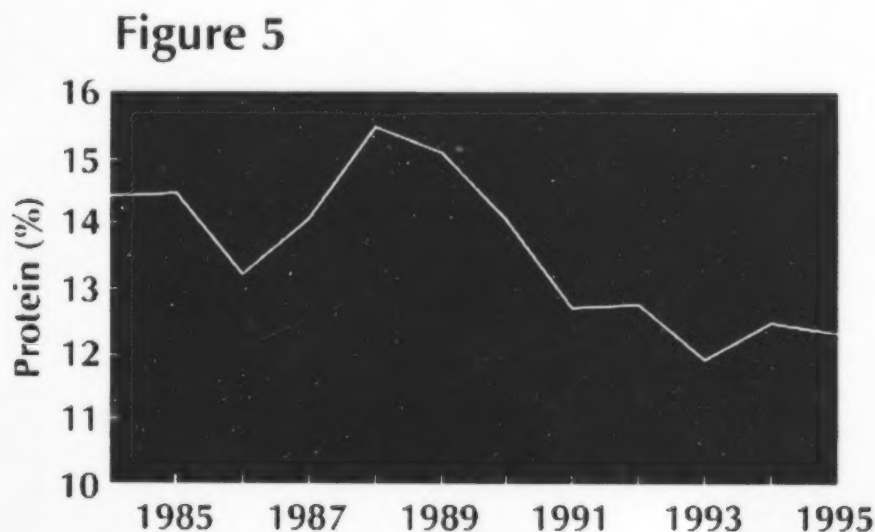
Source: McCraig and Clarke (1995)

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Figure 5. Protein content of No 1 CWAD wheat by year.



Source: Canadian Grain Commission harvest survey survey data

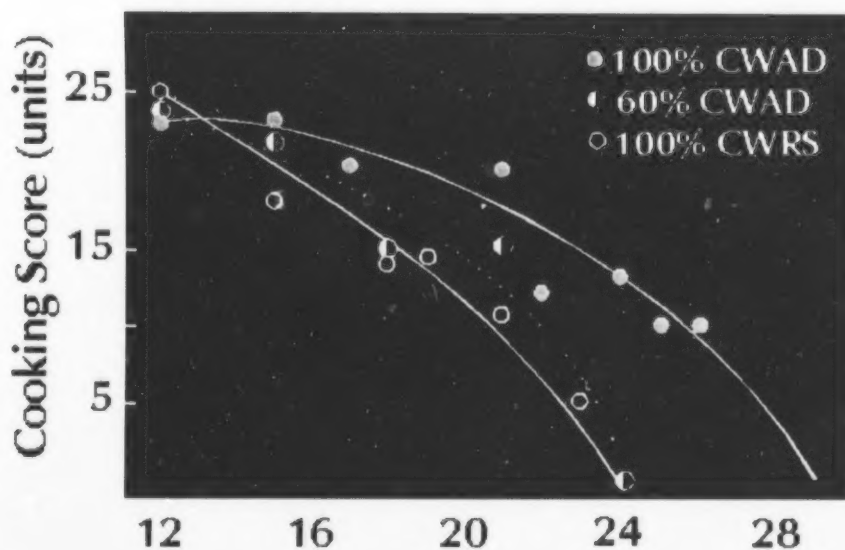
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Figure 6. Effect of addition of hard red spring wheat farina to durum wheat semolina on spaghetti cooking quality.

Figure 6



Source: Dexter et al (1981b)



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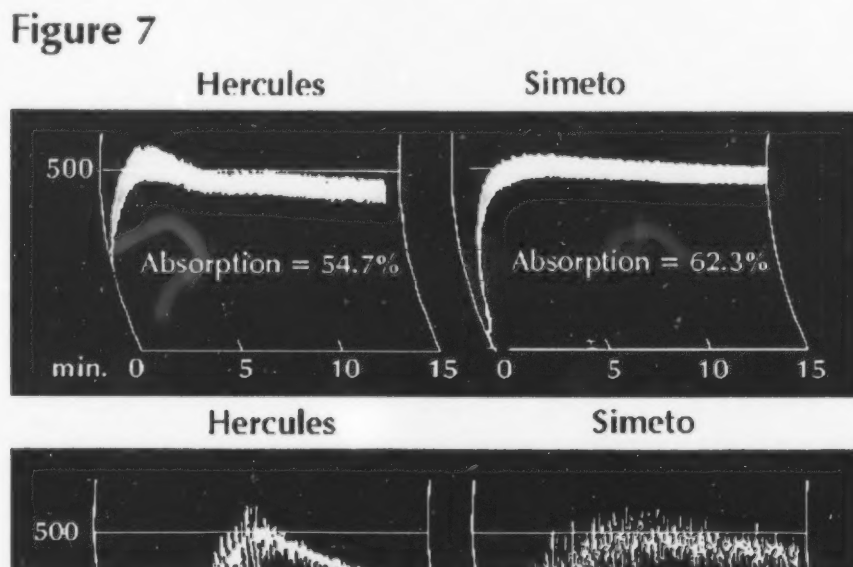
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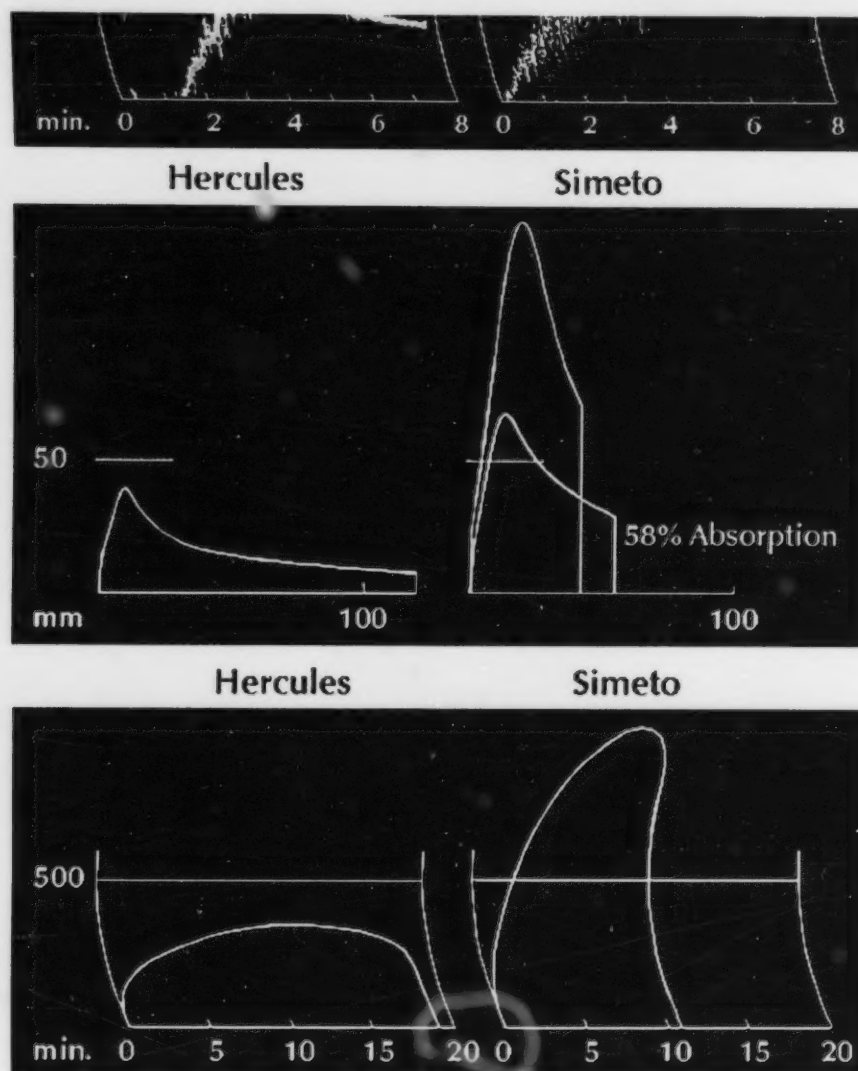
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Figures 7 and 8

Figure 7. Farinograph (top), Mixograph (second) at bread dough absorption, Alveograph (third) and Extensigraph (bottom) curves for Canadian durum wheat standard variety Hercules and the Italian durum variety Simeto. The Simeto Alveograph was obtained at standard (50%) absorption and at 58% absorption.





Sources: Hercules: 1995 Canadian durum wheat screening, Simeto: Dexter and Marchylo (unpublished data)

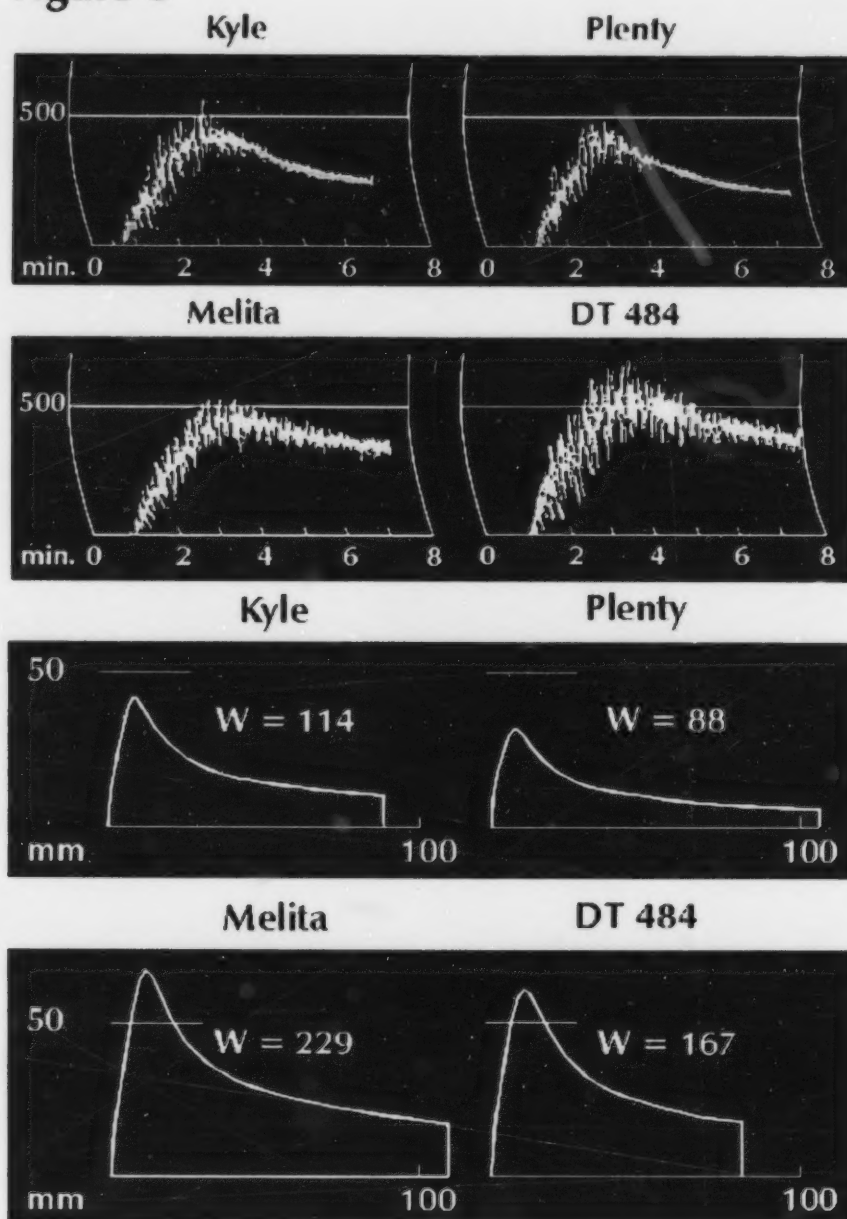
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Figure 8. Mixograph (top) and alveograph (bottom) curves for some Canadian durum wheat varieties.

Figure 8



Source: 1995 Canadian durum wheat screening program

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